1

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

TRADEX VHF RADAR

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Group 45

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LEXINGTON MASSACHUSETTS

TRADEX VHF RADAR

I. GENERAL

The newly installed TRADEX VHF Radar Subsystem will enable Project PRESS to gather, at a frequency of 149 MHz, signal returns from exo-atmospheric and re-entering bodies and their wakes. The VHF Radar is built into the TRADEX system and utilizes many of the existing facilities such as the antenna and the data processing and recording subsystems. The radar, being a non-tracker, will rely on the UHF Radar for positioning in range and angle.

The VHF transmission is of right circular polarization with any one of the following waveform options:

a. A fifty microsecond, one megacycle linearly chirped pulse of rectangular shape

b. A fifty microsecond, one megacycle linearly chirped pulse with amplitude pre-weighting in the form of a half-sine-wave on a rectangular pedestal

c. A one microsecond CW pulse.

A three-channel receiver enables reception of the principal polarization return on two of the channels and the orthogonally polarized return on the third channel. Target data on both senses of polarization are recorded on IF tape, and "A-scope" and RTI film. An IF tape playback feature enables post-mission amplitude and phase processing of VHF data by the Scintillation Data System (SDS). A "quick change" patching network will also allow SDS recording of "live" VHF data on certain missions. VHF power and mode bits are

recorded on both computer and DCFU tape. The prinicpal operating parameters of the VHF radar are listed in Table I. Figure 1 and Table II are a sensitivity vs. range plot and a sensitivity calculation, respectively, of the VHF radar, while Fig. 2 presents a block diagram of the system.

TABLE I

VHF Radar Parameters

Frequency	149 MHz
Peak power	
Rectangular chirp mode	333 kw
Shaped chirp mode	480 kw
One microsecond pulse	480 kw
Average power	
Rectangular chirp mode	25 kw
Shaped chirp mode	24 kw
One microsecond pulse	710 w
Pulse widths	50 μsec compressed to 1 μsec (nominal); 1 μsec
PRF	1482 nominally, varies from 371 pps to 1819 pps
Antenna	84' dia. parabolic
Antenna feed	4 slotted cavities
Antenna gain	27.8 db
Antenna beamwidth	
Azimuth	5.1°
Elevation	5.3°

Antenna sidelobe level	
Azimuth	-16 db
Elevation	-16 db
Polarization	RHC transmit; LHC, RHC receive
Transmit microwave loss	1.0 db
Receive microwave loss	1.0 db
Receiver channels	
Left circular normal (LCN)	Manual gain controlled channel for reception of principal polarized returns
Left circular fixed gain (LCFG)	Fixed gain controlled channel for reception of principal polarized returns
Right circular normal (RCN)	Manual gain controlled channel for reception of orthogonal polarized returns
Receiver noise figure	
Left circular channel	3.1 db
Right circular channel	3.3 db
System noise temperature (antenna terminals)	
LC channel	771°K
RC channel	809°K
Range sidelobes (all channels)	-24 db
Sensitivity (single pulse S/N on a -20 dbsm target at a range of 75 NM)	+12.1 db

II. ANTENNA, FEED, AND MICROWAVE

The VHF feedhorn assembly consists of four slotted cavity radiators axially symmetrical and coaxial with the present UHF/L-Band feed. The VHF feed is designed to replace the four trapazoidal correcting plates which help to form the UHF angle error patterns. The face plate of each slotted cavity is mounted in a plane normal to the boresight axis and extends from the UHF error horns to the feed support arms. The VHF slot is located on the edge of the face plate adjacent to the UHF error horn. Opposite slots are approximately one-half wavelength apart yielding near optimum illumination of the 84 foot TRADEX parabola. The VSWR of the VHF feed is 1.2 or less over a bandwidth of 4 MHz. Cross coupling between the UHF/L-Band feed and the VHF feed is less than -30 db. The axial ratio of the VHF primary beam pattern is 1.02:1.

The microwave path consists of coaxial transmission line and components throughout. A single 3-1/8" coaxial run is used between the transmitter and the first power splitting $\pi/2$ hybrid which forms the H and V components. Two 3-1/8" coaxial runs are then carried up through the antenna pedestal via azimuth rotary joints. One of the coaxial runs employs a phase shifter prior to the duplexer to adjust for optimum transmit polarization ellipticity. Final π hybrids are located behind the parabolic reflector and further split the two 3-1/8" coaxial runs into four 1-5/8" coaxial transmission lines. Each pair of 1-1/5" co-ax are run along the feed support arms to opposite cavities to form the circularly polarized transmission. On reception the circularly

polarized principal and orthogonal returns are combined in the π hybrids and the $\pi/2$ hybrid at the duplexer receive port to form the LC and RC received signals for the three-channel receiver. The receive microwave consists of a phase shifter in one of the receive lines to independently adjust the receive polarization ellipticity. All of the high power microwave components and feed are pressurized to one-half pound psi with dry air to minimize arcing under high power. The transmit polarization ellipticity is 1.08:1. The transmit power unbalance at the inputs to the four VHF cavities is less than 0.5 db.

III. VHF TRANSMITTER

The VHF transmitter chain consists of five negative-grid, tetrode tubes in resonant cavities. A crystal controlled stalo signal is multiplied to 209 MHz and mixed with either a 60 MHz, 60 μsec linear chirp pulse from the TRADEX active exciter for chirp transmission, or a 60 MHz, 1 μsec CW pulse for the 1 μsec transmission. The 149 MHz pulse is then fed via a solid state low level amplifier and gating circuit to the chain of IPA and HPA stages. The grids of the 7651 IPA stages are biased off except during transmission. The screen grid circuit of the 7214 driver stage is used to control the shape of the RF transmitted chirp pulse. It determines the width of the rectangular pulse and, in addition, modulates the driver to form the shaped chirp pulse. The configuration of the shaped chirp pulse with a 50 per cent pedestal height is such that a constant energy per pulse is maintained between "rectangular chirp" and "shaped chirp" transmissions.

Both the screen and plate of the 4616 power output amplifier are pulsed. The plate is pulsed by the HPA modulator which provides a 25 Kv video pulse bracketing the RF pulse, and the screen is pulsed by a separate regulated screen pulser which derives its video pulse energy from the plate modulator. The output power level can be varied from full peak to 15 db below peak by adjustment of the HPA plate video pulse.

The PRF and transmitter timing triggers are controlled by start and stop triggers derived from the TRADEX range tracker. The gain of the transmitter chain from exciter to the output of the HPA is 72.2 db and the 3 db bandwidth is 3.35 MHz. The phase variation from linearity across the 50 μsec rectangular chirped pulse is approximately ± 2.5°.

IV. RECEIVER

The VHF receiver consists of three channels, two of which are used for the principally polarized returns (one channel employing manual gain control, the other fixed gain) and the third one for the orthogonal polarization, employing manual gain control. The front end is a low noise solid state preamplifier with a noise figure of 2.5 db and a gain of 20 db. The gain of the IF amplifier-mixer in each of the two "normal" or gain controlled channels is capable of being controlled over a 70 db range in 5 db steps by use of a manual gain control switch on the operators console. The fixed gain channel is usually left at fixed gain (nominally maximum) throughout a mission. In the chirp mode of operation the receiver employs a lumped constant compression network matched to the transmitted chirp characteristic followed by a Gaussian shaped weighting filter. In the chirp mode the receiver bandwidth is 450 KHz.

An alternate non-compression path is used for one-microsecond operation. The receiver bandwidth in this case is 2 MHz and is determined by the narrow band filter.

The received signals from all three channels are extracted from the sum-and-distribution amplifiers at 1.5 MHz IF and sent to the IF tape recorders. In addition, the signals are converted to 11 MHz in the doppler mixer for distribution to the SDS. The two normal gain channels are also fed via logarithmic amplifiers to oscilloscopes for photographic recording, and to a viewing "scope" on the operators console.

The receivers are capable of providing, at full gain, an output level of 1 volt RMS linear into 75 Ω. The noise gain of the receiver in chirp mode is approximately 85 db with an additional compression gain of 16 db for the signal. The input noise level is -113 dbm. The input signal sensitivity (considering a 16 db compression gain) is -129 dbm. The chirp receiver gain of 85 db results in an output noise level in the normal channel of -28 dbm which is equivalent to an SDS count of 20 or approximately 10 db above IF tape noise. The fixed-gain channel gain is adjusted 5 db lower to provide an SDS count of 15 or 5 db above tape noise. A one volt p-p output from the normal chirp receiver is equivalent to an SDS count of 50 or approximately 10 db below the receiver saturation level. The instantaneous dynamic range of the receiver is 45 db at full gain and 60 db with a receiver gain reduction of 20 db or more. The dynamic range is further limited by the IF tape to approximately 30 or 35 db. The input stages of the receiver prior to the gain controlled IF amplifier-mixer saturate at an input level of -30 dbm.

V. DATA RECORDING*

The following is the present data recording configuration for the VHF radar:

A. IF Tape Recorder Patch Configuration

Channel	TRADEX Tape	TDRC Tape	TDRC Dub
2		VHF LC FG	
8	VHF LC FG		VHF LC N
10		VHF RC N	
12	VHF LC N		

B. SDS Recording

At present there are no plans for SDS recording of "live" VHF data. An alternate SDS patch is utilized for SDS recording of pre and post mission sphere calibrations and post mission IF tape playback. The following alternate patch configuration is used for VHF:

SDS Channel	SDS Range Gates
1. VHF LCN	1 - 9
2. VHF LCFG	1 - 9
3. VHF RCN	1 - 9

C. Analog Recorder No. 1 and 3 (Strip Chart)

Channel	Parameter	Scale
6	VHF Power	1.25 volts/div

* A more detailed description of the PRESS data recording configuration is available in TRADEX Data Evaluation, Revision, Lincoln Manual 54, 14 December 1964.

D. Photo Recording

1. RTI No. 3

Signal	Pretrigger	Sweep	Total Trace
VHF LCN	-6 Kyds	10 μsec/cm	16.5 Kyds

2. A-Scope No. 1 (Bottom Trace)

Signal	Pretrigger	Sweep	Total Trace
VHF LCN	-26 Kyds	100 μsec/cm	164 Kyds

E. DCFU and Computer Tape

The following VHF mode bits and parameters are recorded:

1. VHF peak power
2. LC and RC manual gain setting (4 bits)
3. 1 μsec/chirp
4. Rectangular/shaped

RGS/plm

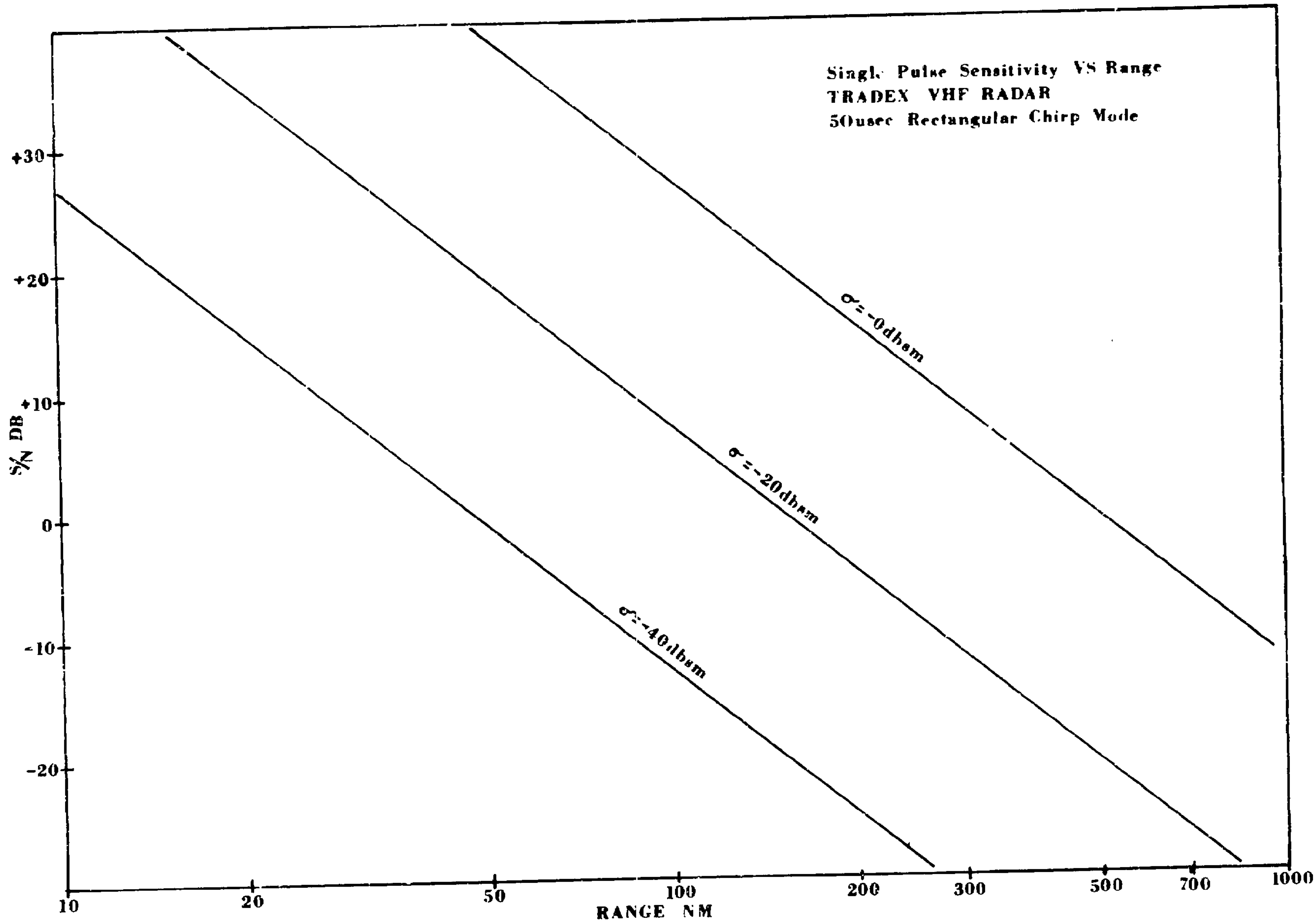
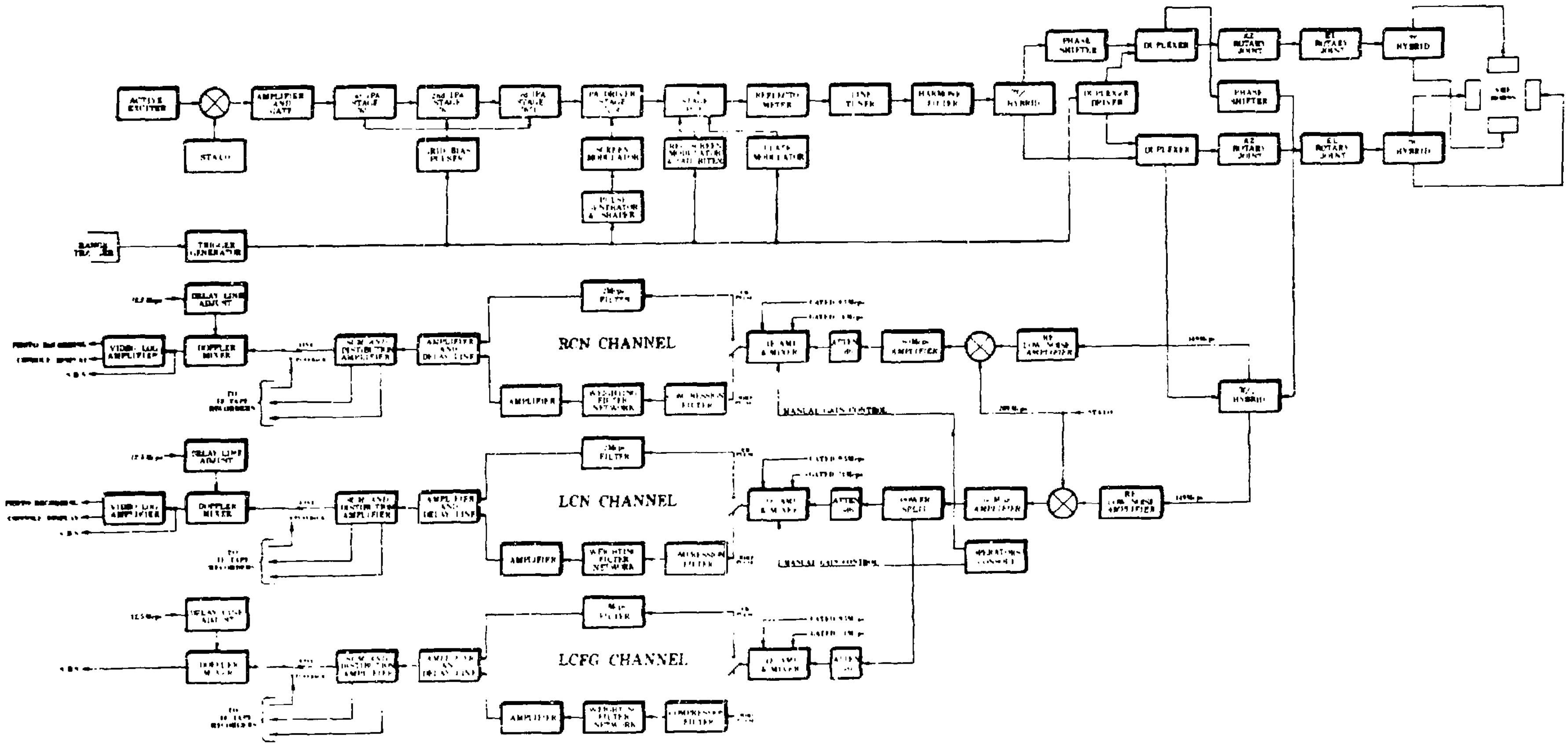


Fig. 1. Single pulse sensitivity VS range TRADEX VHF RADAR 50 usec rectangular chirp mode.



TRADEX VHF BLOCK DIAGRAM

Fig. 2. TRADEX VHF block diagram.

TABLE II

$$\frac{S}{N} = \frac{P_p \, \tau \, G_t \, \lambda^2 \, \sigma_T}{(4\pi)^3 \, R^4 \, k \, T_r \, L_{et} \, L_{er} \, L_{pt} \, L_{pr} \, L_{nir}}$$

Quantity		Value: Numerical	Value: db	Computation: + db	Computation: - db
P_p	Peak transmitter power* (Mw)	0.33			
τ	Pulse length (μsec)	50			
	Energy per pulse (joule)	16.5	+ 12.18	12.18	
G_t	Transmitting-antenna gain**	27.79	27.79	27.79	
G_r	Receiving-antenna gain**	27.79	27.79	27.79	
σ_T	Target back-scattering cross-section (m^2)	.01	- 20		20.0
λ	Wavelength (m)	2			
	$\lambda^2 (m^2)$	4	6.0	6.0	
$(4\pi)^3$		1984.4	+ 33.0		33.0
R	Range (nm)	75			
	$R^4 (nm)^4$	3.22×10^7	+ 75.0		75.0
Range-conversion factor	$(1852)^4$ $(m/nm)^4$	1.1764×10^{13}	+ 130.7		130.7
k	Boltzmann's Constant (joule/°K)	1.38×10^{-23}	- 228.6	228.6	
T_r	Effective receiving-system temperature (°K) measured at preamp input	600	+ 27.78		27.78
L_{et}	Equipment loss-transmission	1 db			1.0
L_{er}	Equipment loss-reception	1 db			1.0
L_{pt}	Propagation loss-transmission				
L_{pr}	Propagation loss-reception				
L_{nir}	Non-ideal-receiver loss	1.8			1.8
	Sub Totals			302.36	290.28
	Single-pulse IF signal-to-noise ratio			+ 12.08	

$T_r = T_{sky} + T_{loss} + T_{preamp}$

$T_{sky} = 236°K$

$T_{loss} = 61°K$

$T_{preamp} = 303°K$

$T_o = 297°K$

* Average transmitter power during the pulse

** Over a lossless isotropic radiator of appropriate polarization

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